SYNOPTIC MONITORING OF WATER QUALITY AND TRACE ELEMENTS IN WATER, SEDIMENT, AND VEGETATION AT RUBY LAKE NATIONAL WILDLIFE REFUGE, SEPTEMBER 1993

by

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INTRODUCTION

Data on environmental contaminants in water, sediment, and biota at RUby Lake National wildlife Refuge (NWR) in eastern Nevada are limited to organochlorine pesticide and polychlorinated biphenyl residues in bird eggs. Henny et al. (1984, 1985) reported on these residues in wading bird eggs collected in 1979-83 that were related to reduced productivity. The source of contamination, at least for black-crowned night-herons *(Nycticorax nycticorax),* was from southern wintering grounds rather than the breeding area (Henny and Blus 1986). Data on these contaminants (as well as mercury in a more limited sample) in canvasback *(Aythya valisineria)* eggs collected in 1972-73 also have been reported (Stendell et al. 1977). However, data were not available on residues of various elements in water, sediment, and biota from this site.

water quality problems caused by irrigation drainage at various sites in the western united states have been identified (Lemly et al. 1993). Two such sites in Nevada, stillwater NWR and vicinity (Hoffman 1994) and the Humboldt wildlife Management Area (WMA) (Seiler et al. 1993), have been evaluated under the National Irrigation Water Quality Program. Data on specific conductance of water, and trace elements in water, sediment, and aquatic vegetation from Ruby Lake NWR, a relatively pristine area in Nevada, were collected in 1993.

The objectives of the study were to: (1) Obtain background data for an area unaffected by irrigation drainage; (2) obtain baseline information from the Ruby Lake NWR so that later possible contaminant impacts could be quantified; and (3) provide comparative data for areas where irrigation drainage or mining impacts are present.

Geoffrey Ekechukwu, Daniel Pennington, and Deborah Poelker assisted with sample collection. Janet Bair identified the plant samples.

STUDY AREA

Ruby Lake NWR is located in southwestern Elko County and northwestern White Pine County of northeastern Nevada (Figure 1). The 15,230 hectare (37,632 acre) refuge lies at the eastern base of the Ruby Mountains within a closed drainage basin at an elevation of 1,830 meters (6,000 feet). The refuge consists of marshes, open ponds, and islands that are surrounded by wet meadows and grass/sagebrush-covered uplands. The marshes are fed by over 160 springs on the valley floor. A collection ditch and a system of dikes were constructed along the west-central portion of the marsh to collect and distribute waters from about 45 of these springs. In normal water years, about 4,860 to 5,260 hectares (12,000 to 13,000 acres) of marshlands can be

maintained, with a maximum of about 6,880 hectares (17,000 acres) in wet years.

Most of the lands to the west of the refuge are managed by the u.s. Forest Service, whereas those to the east are managed by the Bureau of Land Management. Private lands adjacent to the refuge include Fort Ruby Ranch to the south (negotiations were underway in 1994 for transfer of these lands to the refuge) and a small community of primarily summer homes at Shantytown on the west-central side of the refuge. The Nevada Division of wildlife operates the Gallagher Fish Hatchery within the refuge boundary on the western side of the refuge. Primary human uses of the refuge include fishing, migratory bird hunting, sight seeing, and wildlife observation.

Over 200 bird species are known to use the refuge. Fifteen different waterfowl species and a variety of other water dependent birds use the refuge. Nesting canvasbacks and redheads *(Aythya americana)* are considered particularly important. Several pairs of trumpeter swans *(Cygnus buccinator)* are residents. Bald eagles *(Haliaeetus leucocephalus)*, golden eagles *(Aquila chrysaetos)*, and prairie falcons *(Falco mexicanus)*, as well as other raptorial species, are present seasonally. Peregrine falcons *(Falco peregrinus)* are rare visitors. The riparian habitat along Cave Creek is used by numerous songbird species.

A variety of mammals are common in the area. These include mountain lions *(Felis concolor)*, bobcats *(Lynx rufus)*, mule deer *(Odocoileus hemionus)*, coyotes *(Canis latrans)*, and muskrats *(Ondatra zibethica)*.

Eight fish species inhabit refuge waters, with all but the relict dace *(Relictus solitarius)* having been introduced. Largemouth bass *(Micropterus salmoides)* were stocked in the 1930's, and several trout species are stocked annually. Lahontan speckled dace *(Rhinichthys osculus* ssp.) from a 1950 stocking are also present.

POTENTIAL CONTAMINANT SOURCES

Several potential sources of contaminants that could impact the refuge are present; however, the threats are currently considered to be minor. These include the following:

1. Two gold mines using heap leach technology about 3 to 5 kilometers (2 to 3 miles) to the south of the refuge;

2. contaminants from the septic systems of about 100 houses on about 16 hectares (40 acres) at Shantytown and from trailers that were previously located on Fort Ruby Ranch;

3. A small landfill on Fort Ruby Ranch at the south end of the refuge. Preliminary evaluation of the landfill with regard to contaminant sources was conducted in 1994 in relation to the possible transfer of the ranch to the refuge;

4. Potential problems with biological oxygen demand, total dissolved solids, fish diseases, and fish disease control chemicals from the fish hatchery;

5. Past agricultural practices on lands to the north (circle irrigation) from underground seepage to refuge marshes, and grazing practices;

6. The abandoned star Tungsten Mine on Harrison Pass Creek to the northwest of the North Sump, although it is unlikely that water from the creek reaches the refuge due to diversions by a local rancher;

7. Hot springs on the northeast side of North Sump, although water from the springs does not likely reach the sump (the springs are just outside the refuge boundary); and

8. Boron accumulation in arid basins of Nevada, especially in relation to transport to the earth's surface by thermal waters (Smith 1964).

METHODS

Samples of water, sediment, and aquatic vegetation were collected on September 15, 1993, from each of 15 sites on Ruby Lake NWR. At each site, specific conductance (microsiemens per centimeter; µS/cm) was measured with a Fisher scientific Company digital conductivity meter (three readings per site). Collection sites were selected near the inlets and outlets of several marsh units, above and below the fish hatchery along the water collection ditch, and at several sites on the South Sump. Collection sites are described in Table 1 and shown in Figure 1.

One unfiltered water sample was collected in a 250 ml chemically clean nalgene jar at each site. Collection records do not indicate whether or not the samples were acidified at or shortly following collection. Sediment samples were collected with a core sampler (Wilco Wildlife Supply Co., Model 2422-H12); the top 2-5 cm layer of sediment at one or more locations at each site was pooled and placed in a chemically clean jar. Sediment sample weights exceeded 260 g. One aquatic vegetation sample was collected with a gloved hand at each site and placed in a chemically clean glass jar; sample weights ranged from 40 to 64 g. Samples were placed on ice following collection.

SUbsamples of aquatic vegetation that had been collected at sites 1, 4, 6, and 8 were later identified as marestail *(Hippuris vulgaris)*. Samples collected at the remaining sites appeared to be widgeongrass *(Ruppia maritima)*, although no reproductive structures were present for confirmation of the identification.

Samples were analyzed by the Environmental Trace Substances Research Center, Columbia, Missouri, under contract of the Patuxent Analytical Control Facility (PACF) of the National Biological Service, Laurel, Maryland. Analyses were conducted under the quality control/quality assurance plan of PACF.

Arithmetic mean concentrations of trace elements were calculated when more than 50 percent of the values had detectable concentrations. One-half of non-detectable concentrations were used in calcUlating means.

RESULTS AND DISCUSSION

Specific Conductance

specific conductance of water at most sites was low, with mean values of <550 µS/cm at all but one site (Table 2). The highest specific conductance was found at the southern end of the South Sump (site 14) where water levels were low due to evaporation. Specific conductance values were consistently lower at the inlet area of each wetland unit than at the outlet area, or terminal area in the case of the South Sump. These specific conductance values are consistent with or lower than those found for background sites, such as the Carson River below Lahontan Reservoir or the Truckee Canal (Hoffman et al. 1990a; Rowe et al. 1991), and are indicators of good water quality.

Water Samples

Trace element analytical results for water samples are given in Tables 3A and 3B. Causes for variable detection limits for selenium, cadmium, chromium, lead, and nickel are unknown. Boron, barium, magnesium, and strontium concentrations tended to be higher at the outlet area of specific wetland units than at the corresponding inlet area. These results are consistent with information on specific conductance at these sites.

Arsenic. Concentrations were below the detection limit of 0.4 µg/L in 8 of 15 samples. The highest concentration (74 µg/L) was found at the south end of the South Sump (site 14). Prior to 1991, the regulatory standard in Nevada (Nevada Administrative Code 1994 [NAC]) for the protection of aquatic life was 40 µg/L total arsenic. Current standards are based on species of arsenic, which were not analyzed in this study. Only the sample from site 14 contained a concentration in excess of the earlier criteria, probably due to turbidity and evaporative loss at time

of collection. Concentrations in all remaining samples were far below this standard. For comparative purposes, Carson River water had a median of 16 µg/L with a range of 7 to 45 µg/L (Lico 1992). Arsenic concentrations were also higher in water samples from Humboldt River reference sites ($\bar{x}$ = 29 µg/L; range 14 to 59; Seiler et al. 1993). Except for the sample from site 14, all samples contained concentrations far below those associated with adverse effects on aquatic life (Birge et al. 1980; U.S. Environmental Protection Agency [EPA] 1985).

Selenium. Only one sample contained a detectable concentration (1 µg/L). Detection limits were variable, ranging from 0.4 to 2 µg/L. The NAC established a 96-hour average standard of 5 µg/L for the protection of aquatic life. However, Skorupa and Ohlendorf (1991) found that concentrations between 1 and 3 µg/L were associated with levels in bird eggs that caused mortality or embryonic deformity. The concentrations in water samples from Ruby Lake NWR were generally well below concern levels. Selenium was not detected in Carson River water samples, with a detection limit of 1 µg/L (Lico 1992). Selenium was not detected at >1 µg/L in water from reference sites on the Humboldt River (Seiler et ale 1993).

Mercury. No sample contained a detectable concentration, with consistent detection limits of 0.2 µg/L. NAC established the 96-hour average standard for protection of aquatic life at 0.012 µg/L. Our detection limit was far above this standard. Mercury was seldom detected (0.1 µg/L detection limit) in water samples from Humboldt River reference sites (Seiler et al. 1993).

Boron. Only six samples contained detectable concentrations, with the highest concentration (420 µg/L) again being found at site 14. This was below the standard (550 µg/L) set in the NAC for the protection of aquatic life. The median concentration of boron in Carson River water was 360 µg/L with a range of 110 to 730 µg/L (Lico 1992). Boron concentrations in water samples from Humboldt River reference sites (Seiler et ale 1993) were much higher than in those from Ruby Lake NWR.

Aluminum. Detectable concentrations were found at only six sites, with the highest concentration (7150 µg/L) at site 14. For waters of pH 6.5 to 9.0, Federal water quality criteria specify that levels should not exceed 87 µg/L more than once every 3 years (EPA 1988). All detectable concentrations in this study were above the criteria. Aluminum toxicity varies considerably with chemical species and complexation, with toxicity lower at elevated pH (EPA 1988). The pH of Ruby Lake NWR waters is likely above 8; therefore, concerns regarding aluminum toxicity are somewhat reduced.

Barium. The mean concentration was 213 µg/L, with extremes of 58 and 515 µg/L. The NAC does not establish a standard for the protection of aquatic life, but limits water for municipal or domestic use to 1,000 µg/L.

Beryllium. The sample from site 14 contained the only detectable concentration, with samples from the remainder of the sites all having <0.2 µg/L. There is no standard for this element for the protection of aquatic life in the NAC.

Cadmium. No detectable concentrations were found, with detection limits varying between 0.6 and 2 µg/L. Water quality standards in the NAC are dependent upon hardness. We have no data on hardness; therefore, we are unable to provide interpretation. The non-detectable cadmium levels are not cause for concern.

Chromium. The only sample containing a detectable concentration was from site 14. The remaining samples had variable detection limits of 3 and 10 µg/L. The standard for chromium +3 in the NAC is based on hardness. The 96-hour average standard for chromium +6 is 10 µg/L.

Copper. All but one sample had <2 µg/L. The remaining sample, from site 14, contained 5 µg/L. The standards in the NAC are based on hardness. The levels present are of no concern.

Iron. The mean concentration, excluding the sample from site 14 (4140 µg/L), was 46 µg/L. TWo samples had non-detectable concentrations. The NAC established a standard for the protection of aquatic life of 1,000 µg/L. Only the sample from site 14 exceeded this concentration, likely due to turbidity and evaporative water loss.

Lead. Only two samples contained detectable concentrations, with the remainder having variable detection limits of 10 or 40 µg/L. The NAC standard for protection of aquatic life is based upon water hardness.

Magnesium. Excluding the high concentration at site 14, the mean for the remaining samples was 23,000 µg/L. There is no standard in the NAC for this element.

Manganese. Most samples contained non-detectable concentrations, with the highest concentration (130 µg/L) in the sample from site 14. The only standard (200 µg/L) in the NAC for this element is for irrigation.

Molybdenum. All samples contained <10 µg/L. The NAC established a standard for the protection of aquatic life of 19 µg/L. All samples were below this criteria.

Nickel. Few samples had detectable concentrations. Detection limits were variable (3 and 20 µg/L). The NAC standards for the protection of aquatic life are dependent on water hardness.

strontium. The mean concentration was 102 µg/L, excluding the sample from site 14. No standard in the NAC exists for this element.

Vanadium. only the sample from site 14 (16 µg/L) had a detectable concentration, with the remainder all below 3 µg/L.

Zinc. The only sample containing a detectable concentration was that from site 14 (24 µg/L), the remainder being <5 µg/L. The standard in NAC for this element is based on water hardness.

In summary, trace element concentrations in water samples from Ruby Lake NWR, with the exception of aluminum, were low and below water quality standards or levels of concern with regard to effects on aquatic life.

Sediment Samples

Results of analyses of sediment samples are given in Tables 4A and 4B. Concentrations of arsenic, boron, barium, manganese, strontium, and vanadium were lower at the inlet area of specific wetland units than at the outlet area of the same units. This corresponds with the information on specific conductance and some data on elements in water at these sites. The results are compared with those found for lake bottom sediments at stillwater WMA and vicinity and Fernley WMA and vicinity (Lico 1992), and for reference areas for the Humboldt WMA (Seiler et al. 1993) in Table 5. A discussion of the results for a few elements of concern, where interpretative data are available and needed, is given below.

Arsenic. The mean arsenic concentration was 5.9 ppm, with extremes of 0.4 and 16 ppm. Long and Morgan (1991) identified an "Effect Range-Low" (10th percentile) to aquatic invertebrates in marine and estuarine sediments of 33 ppm and Persaud et al (1993) identified a lowest effect level to benthic invertebrates of 6 ppm arsenic in sediment. Five of 15 samples contained >6 ppm arsenic, but none contained more than 33 ppm.

Mercury. Thirteen of 15 samples had non-detectable «0.01 ppm) concentrations, while the remaining two had 0.02 ppm. These concentrations are similar to or below those in bottom sediment samples from the Fernley WMA, an area of no known mercury input (Lico 1992). Lake bottom sediment samples from the stillwater WMA and vicinity contained much higher concentrations (Lico 1992). Mercury contamination of the stillwater WMA area

occurred from losses associated with its use in gold and silver recovery near the Carson River, upstream of the area.

Correlations. strontium concentrations in water and sediment were positively correlated (r^2 = 0.388; P <0.05; n = 15). No other significant correlations occurred between water and sediment for individual elements.

Vegetation Samples

Trace element concentrations in vegetation are presented in Tables 6A and 6B. The collection of different species of vegetation complicated interpretation of the results. The sample from site 1 had the highest concentration of 8 of 18 trace elements in which detectable concentrations were found, and had the second or third highest concentration for six of the remaining trace elements. We are unaware of manmade trace element sources for this site.

Arsenic. Concentrations in these samples, except for that from site 14, were lower than concentrations found in algae and pondweed samples from Carson Valley (Hoffman et al. 1990a). Concentrations in Ruby Lake NWR samples are far below those adversely affecting mallard *(Anas platyrhynchos)* duckling growth and behavior (Whitworth et al. 1991; Camardese et al. 1990).

Selenium. Concentrations were consistently low, similar to those in algae and pondweed from Carson Valley (Hoffman et al. 1990a), and far below dietary effect levels for waterfowl of about 5 ppm (Heinz et al. 1989; Skorupa and Ohlendorf 1991).

Mercurv. Concentrations were extremely low and far below dietary effect levels for waterfowl of about 0.5 ppm (Heinz 1979) •

Boron. Concentrations were similar to those in algae and pondweed in areas impacted by agricultural drainwater (Hoffman et al. 1990a). Samples of marestail had consistently low boron concentrations ($\bar{x}$ = 15.5 ppm; range 12-19 ppm), whereas widgeongrass samples had concentrations ranging over two orders of magnitude (range 12-1240 ppm; $\bar{x}$ = 453 ppm).

Female, but not male, mallard ducklings receiving diets containing 100 and 400 ppm boron had reduced growth rates and delayed growth (Hoffman et al. 1990b). A significant decrease in brain ATP concentration, indicative of altered brain energy metabolism, also occurred in the group receiving 400 ppm boron. Hoffman et al. (1990b) concluded that "••• concentrations greater than 100 ppm B occurring in aquatic vegetation could adversely alter duckling development.ıı smith and Anders (1989) fed adult mallards and their young diets containing boron. Hatching

weights of ducklings whose parents received 300 and 1000 ppm boron, and weight gain of those that received 30, 300, and 1000 ppm boron, were significantly depressed from those of controls.

Aluminum. Although aluminum concentrations in some water samples appeared elevated, concentrations in Ruby Lake NWR vegetation samples were far lower than those in algae from stillwater WMA and vicinity (Rowe et al. 1991), and generally lower than in algae and vegetation samples from the Humboldt WMA and vicinity (Seiler et al. 1993). The aluminum concentrations in vegetation at Ruby Lake NWR were well below an avian dietary effect level of 5,000 µg/g (Sparling 1990; Miles et al. 1993).

other Elements. Concentrations of the remaining elements are below known dietary effect levels and are, therefore, not cause for concern.

Correlations. The correlation of concentrations of individual trace elements between vegetation and sediment was explored for sites where widgeongrass was collected. significant positive correlations were found only for arsenic (r^2 = 0.445; P <0.05; n = 11) and zinc (r^2 = 0.826; P <0.01; n = 11). Magnesium residues in water and widgeongrass samples were also positively correlated (r^2 = 0.681; P <0.01; n = 11).

CONCLUSIONS AND RECOMMENDATIONS

Trace element concentrations in water, sediment, and aquatic vegetation at Ruby Lake NWR were generally low and representative of normal background levels in Nevada. The exceptions for selected samples were: Aluminum in water, arsenic in sediment, and boron in vegetation. Additional data on boron concentrations in waterfowl food items at Ruby Lake NWR should be collected to determine if other dietary items contain excessive concentrations of boron. If boron residues are excessive in a significant proportion of waterfowl food items, juvenile waterfowl should be collected for trace element analysis, especially boron. Sampling of water, sediment, and biota at Ruby Lake NWR should be conducted every 5 years to monitor conditions. Future collections should include samples of aquatic invertebrates, fish, and bird eggs.

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Table 1. Location of sampling sites at Ruby Lake National wildlife Refuge, Nevada, September 15, 1993.

site No."	Location Description
1	Northwest corner of marsh unit 10; inlet from collection ditch.
2	Southeast corner of marsh unit 10, near outlet.
3	Northwest side of marsh unit 13, near inlet.
4	Southwest corner of marsh unit 13, in stagnant area below nearby dump.
5	Northwest side of marsh unit 14, near inlet.
6	Southwest corner of marsh unit 14, near outlet (stagnant end).
7	Northwest side of marsh unit 20, at inlet.
8	Water collection ditch above fish hatchery.
9	Southeast end of marsh unit 20, near outlet.
10	Outlet of water collection ditch, below fish hatchery, near west end of marsh unit 21.
11	South side of marsh unit 21, at outlet.
12	Northwest end of South Sump, near inlet.
13	West side of South Sump, at main boat landing.
14	South end of South sump, near Narciss boat landing.
15	In slough below County Line Pond, near mixing zone with South Sump, on west side of South Sump, at Elko-White Pine County line.

" See Figure 1.

Table 2. Specific conductance (µS/cm) of water at selected sites on Ruby Lake National wildlife Refuge, Nevada, September 15, 1993.

site No.	specific Conductance Mean	Range
1	295	
2	317	315 - 320
3	241	225 - 250
4	432	423 - 439
5	227	220 - 233
6	410	393 - 418
7	230	224 - 234
8	237	233 - 240
9	538	535 - 542
10	247	240 - 253
11	263	260 - 265
12	228	220 - 236
13	273	266 - 280
14"	1461	1246 - 1575
15	253	200 - 280

" Water levels becoming very low due to evaporation; high turbidity.

Table 3A. Trace element concentrations in water samples collected from Ruby Lake National Wildlife Refuge, September 15, 1993.

site No.	Trace Element Concentrations (µg/L)										
	As	Se	Hg	B	Al	Ba	Be	Cd	Cr	eu	Fe
1	<0.4	<0.5	<0.2	<20	<30	149	<0.2	<2	<10	<2	<10
2	<0.4	<2	<0.2	20	<30	165	<0.2	<2	<10	<2	20
3	<0.4	<0.5	<0.2	<20	240	162	<0.2	<2	<10	<2	140
4	0.8	<0.5	<0.2	50	<30	192	<0.2	<2	<10	<2	10
5	<0.4	<0.5	<0.2	<20	<30	177	<0.2	<2	<10	<2	10
6	1.0	<0.4	<0.2	50	210	279	<0.2	<0.6	<3	<2	140
7	<0.4	<0.4	<0.2	<20	<30	182	<0.2	<0.6	<3	<2	10
8	<0.4	<0.4	<0.2	<20	<30	187	<0.2	<0.6	<3	<2	<10
9	0.6	1.0	<0.2	50	<30	240	<0.2	<0.6	<3	<2	33
10	<0.4	<0.4	<0.2	<20	<30	182	<0.2	<0.6	<3	<2	20
11	0.5	<0.4	<0.2	<20	90	199	<0.2	<0.6	<3	<2	52
12	<0.4	<0.4	<0.2	<20	120	185	<0.2	<0.6	<3	<2	71
13	1.9	<0.4	<0.2	62	<30	58	<0.2	<0.6	<3	<2	20
14	74.	<0.4	<0.2	420	7150	515	0.3	<0.6	7	5	4140
15	0.5	<0.4	<0.2	<20	160	325	<0.2	<0.6	<3	<2	110
Mean	-	-	-	-	-	213	-	-	-	-	319"
SO	-	-	-	-	-	102	-	-	-	-	1058

" Mean - 46, excluding outlier (site 14); SO - 50.

Table 3B. Trace element concentrations in water samples collected from Ruby Lake National wildlife Refuge, September 15, 1993.

site No.	Trace Element Concentrations (f.Lg/L)							
	Pb	Mg	Mn	Mo	Ni	Sr	V	Zn
1	<40	17,300	<2	<10	<20	136	<3	<5
2	<40	22,300	<2	<10	<20	146	<3	<5
3	<40	14,100	4	<10	<20	54	<3	<5
4	<40	46,200	<2	<10	<20	172	<3	<5
5	<40	14,800	<2	<10	<20	51	<3	<5
6	<40	40,200	7	<10	<3	201	<3	<5
7	10	14,600	<2	<10	<3	53	<3	<5
8	<10	14,800	<2	<10	4	53	<3	<5
9	<10	53,800	<2	<10	<3	181	<3	<5
10	<10	15,100	<2	<10	<3	70	<3	<5
11	<10	21,200	3	<10	<3	96	<3	<5
12	<10	15,400	<2	<10	4	75	<3	<5
13	<10	15,400	<2	<10	<3	78	<3	<5
14	20	162,000	130	<10	5	483	16	24
15	<10	17,200	<2	<10	<3	68	<3	<5
Mean	-	32,300[a]	-	-	-	128[b]		
SO	-	38,100	-	-	-	111		

[a] Mean - 23,000, excluding outlier (site 14); SO = 13,300.
[b] Mean = 102, excluding outlier (site 14); SO = 54.

Table 4A. Trace element concentrations in sediment samples collected from Ruby Lake National Wildlife Refuge, September 15, 1993.

site No.	Trace Element Concentrations (ppm dry weight)										
	As	Se	Hg	B	Al	Ba	Be	Cd	Cr	eu	Fe
1	1.5	<0.2	<0.01	7.4	7200	245	0.36	0.4	7.7	6.4	6260
2	11.	<0.2	<0.01	34.	8060	478	0.32	<0.2	6.3	7.8	5250
3	0.4	<0.2	<0.01	5.0	2690	155	0.16	<0.2	5.7	1.7	1980
4	6.2	0.3	<0.01	15.	14600	787	0.71	0.5	13.	14.	9260
5	2.8	<0.2	<0.01	9.3	10500	620	0.54	0.5	10.	9.9	7780
6	16.	0.4	<0.01	45.	7140	807	0.34	0.4	6.3	8.1	4810
7	2.7	<0.2	<0.01	7.4	7700	383	0.42	0.4	7.8	7.0	6400
8	2.7	0.5	<0.01	10.	8100	612	0.37	<0.9	10.	6.2	8480
9	5.3	0.4	<0.01	23.	14000	610	0.63	0.5	14.	11.	8500
10	5.4	1.3	0.02	19.	10400	768	0.48	0.64	11.	12.	7340
11	3.6	0.76	<0.01	10.	12500	777	0.69	<1.0	15.	12.	9150
12	4.0	1.7	0.02	14.	8430	619	0.39	0.3	9.4	9.2	5930
13	9.7	0.3	<0.01	26.	12800	816	0.53	0.79	12.	15.	8740
14	13.	0.5	<0.01	44.	10500	677	0.45	0.4	11.	13.	6760
15	3.6	0.68	<0.01	12.	10800	1150	0.47	0.6	13.	10.	7300
Mean	5.9	0.49	-	19.	9695	634	0.46	0.44	10.	9.6	6929
SO	4.5	0.47	-	13.	3114	248	0.15	0.18	2.9	3.5	1948

Table 4B. Trace element concentrations in sediment samples collected from Ruby Lake National Wildlife Refuge, September 15, 1993.

site No.	Trace Element Concentrations (ppm dry weight)							
	Pb	Mg	Mn	Mo	Ni	Sr	V	Zn
1	10.	79100	130	<1	5.2	87.4	11.	34.5
2	10.	111000	181	<1	3.6	468.	14.	24.0
3.	<4.	104000	106	<1	3.0	87.5	4.5	6.2
4	22.	36000	172	<1	11.	276.	21.	49.8
5	17.	19100	189	<1	7.4	151.	14.	41.9
6	12.	84600	247	<1	5.8	657.	14.	32.2
7	10.	21700	159	<1	9.3	138.	11.	36.9
8	<20.	20800	197	<5	10.	150.	13.	38.0
9	22.	31400	199	<1	8.8	416.	25.	44.7
10	14.	21000	234	<1	8.0	299.	18.	134.
11	<20.	20600	262	<5	8.0	283.	22.	48.0
12	12.	17000	151	<1	6.8	221.	14.	111.
13	30.	16000	211	<1	9.7	399.	23.	51.0
14	15.	27300	190	<1	6.3	519.	21.	46.4
15	16.	13400	228	<1	6.6	264.	15.	32.0
Mean	14.	41533	190	-	7.3	294.	16.	48.7
SO	6.7	34394	43	-	2.3	168.	5.5	32.4

Table 5. comparison of trace element concentrations in sediment among four areas in Nevada. Data for stillwater wildlife Management Area (WMA) and Fernley WMA are for lake bottom sediments in areas impacted by irrigation drainwater, whereas data for Humboldt WMA are for reference sites presumably not impacted by irrigation drainwater.

	Ruby Lake NWR[a]		stillwater WMA[b]		Fernley WMA[c]		Humboldt WMA[d]	
Element	Mean	Range	Median	Range	Median	Range	Median	Range
Arsenic	5.9	0.4-16	16.	8.8-35	40.	20-47	6.1	4.0-9.9
Selenium	0.49	<0.2-1.7	0.40	<0.1-1.2	1.3	0.6-5.0		<0.1-0.3
Mercury		<0.01-0.02	0.48	0.04-18	0.04	<0.02-0.06	0.02	<0.02-0.06
Boron	19.	5.0-45	26.	11-104	59.	40-390	1.0	0.7-2.0
Aluminum	9695.	2690-14600						
Barium	634.	155-1150					1000.	820-1100
Beryllium	0.46	0.16-0.71					2.0	2.0
Cadmium	0.44	<0.2-0.79					<2.0	
chromium	10.	5.7-15	33.	25-100	33.	20-43	28.	24-32
Copper	9.6	1.7-15	37.	22-67	37.	25-49	8.0	6-18
Iron	6929.	1980-9260						
Lead	14.	<4-30	18.	15-46	14.	11-17	21.	16-140
Magnesium	41533.	13400-111000						
Manganese	190.	106-262	700.	530-1200	880.	590-1000	380.	210-680
Molybdenum		<1-<5	4.0	<2.0-9.0	24.	5.0-44	<2.0	
Nickel	7.3	3.0-11					10.	8-13
strontium	294.	87.4-657					445.	240-450
Vanadium	16.	4.5-25	100.	67-190	125.	89-140	62.	50-77
zinc	48.7	6.2-134	83.	57-96	68.	52-87	38.	31-60

[a] This stuay. Samples unscreened.
[b] Data from Lico (1992). Sample size = 18-21. Samples sieved to <2 rom and <62.5 µm fractions; sUbsamples appear to have been combined for analysis.
[c] Data from Lico (1992). Sample size = 5-6. Samples sieved to <2 rom and <62.5 µm fractions; subsamples appear to have been combined for analysis.
[d] Data from seiler et al. (1993). Sample size = 4. Samples sieved to <2 rom.

Table 6A. Trace element concentrations in vegetation samples collected from Ruby Lake National Wildlife Refuge, September 15, 1993.

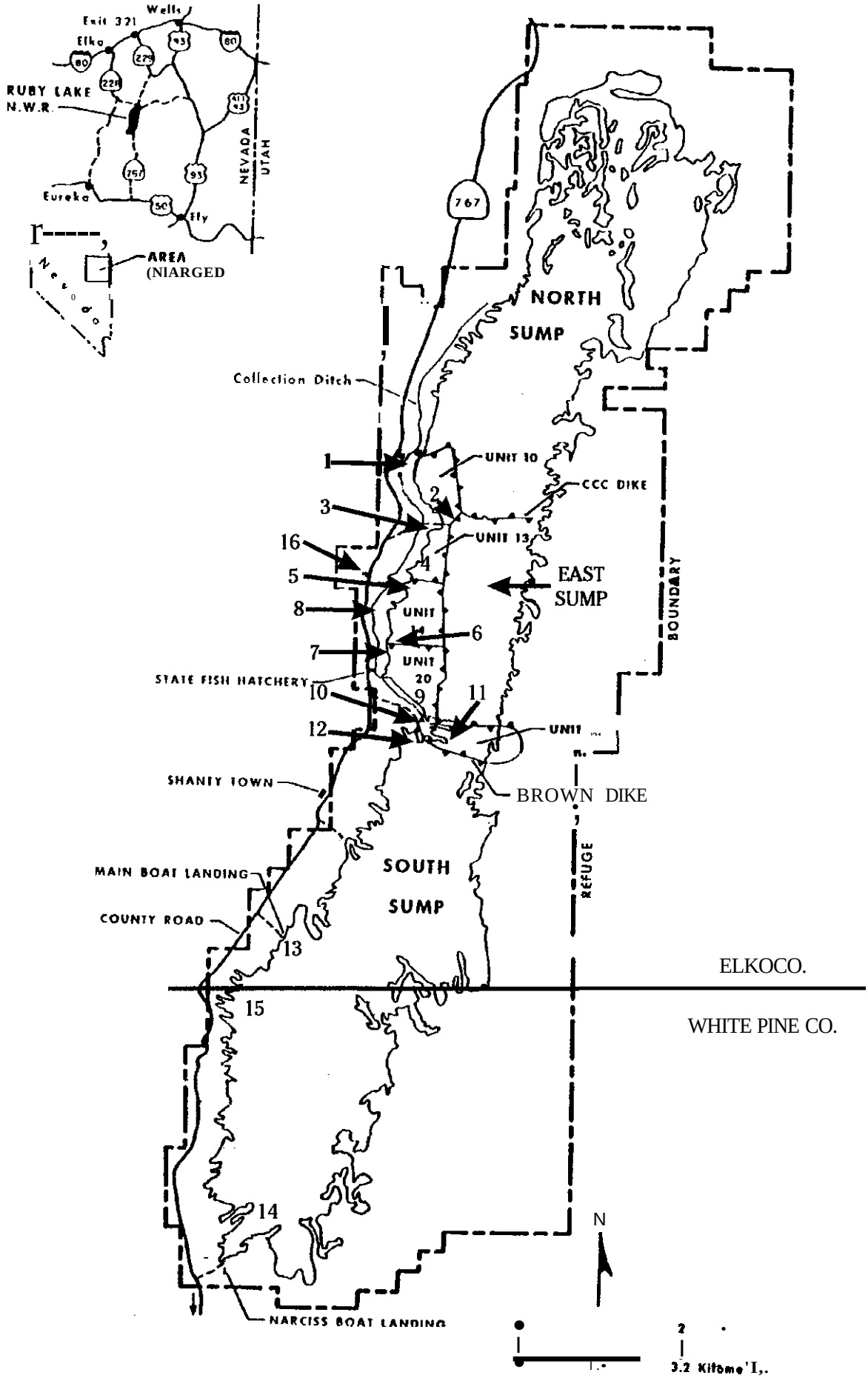
site No.	Trace Element concentrations (ppm dry weight)										
	As	Se	Hg	B	Al	Ba	Be	Cd	Cr	Cu	Fe
1	1.0	0.5	0.01	12	1870	362	0.11	0.14	2.5	3.3	1630
2	0.71	0.2	0.01	160	180	457	0.01	0.03	0.36	1.5	335
3	0.51	0.3	0.006	546	190	562	0.01	0.04	0.62	0.98	244
4	0.30	<0.2	0.024	18	110	193	<0.01	0.069	0.57	1.4	145
5	0.55	0.3	<0.005	644	140	201	0.01	0.04	0.74	1.7	190
6	0.61	<0.2	0.018	19	180	133	<0.01	0.04	0.63	3.2	206
7	0.69	0.3	<0.005	584	200	344	0.01	0.066	0.67	0.74	351
8	0.66	0.3	<0.005	13	19	453	0.01	0.04	0.53	0.40	156
9	0.66	<0.2	<0.005	1240	77	361	<0.01	0.04	0.20	0.96	133
10	0.30	0.3	<0.005	13	51	224	<0.01	0.03	0.51	3.8	101
11	0.90	0.2	0.009	375	170	346	<0.01	0.03	0.49	1.9	140
12	0.60	0.4	0.006	12	1240	243	0.072	0.092	2.4	4.3	966
13	2.8	<0.2	0.022	497	85	169	<0.01	0.14	0.34	3.5	105
14	21.	0.5	0.020	766	851	131	0.073	0.12	0.74	3.1	601
15	0.6	0.3	<0.005	150	382	478	0.03	0.05	1.1	2.5	363
Mean	2.1"	0.27	0.009	337	383	310	0.024	0.06	0.83	2.2	378
SO	5.3	0.13	0.008	370	529	137	0.033	0.04	0.69	1.2	416

" Mean - 0.78, excluding outlier (site 14); SO - 0.61.

Table 6B. Trace element concentrations in vegetation samples collected from Ruby Lake National wildlife Refuge, September 15, 1993.

site No.	Trace Element Concentrations (ppm dry weight)							
	Pb	Mg	Mn	Mo	Ni	Sr	V	Zn
1	3.5	8890	179.	<1	1.8	147.	4.1	34.
2	0.5	6910	149.	<1	0.34	170.	1.2	11.
3	<0.4	5100	79.8	<1	0.30	93.3	0.5	6.9
4	0.4	7050	57.6	<1	0.40	43.8	<0.3	21.
5	0.5	3540	196.	<0.9	0.48	33.2	0.6	14.
6	0.6	6660	82.4	<1	0.49	48.2	<0.3	18.
7	0.4	5140	391.	<1	0.74	45.4	0.94	12.
8	<0.4	4670	376	<1	0.45	46.2	1.3	9.8
9	<0.4	8160	49.2	<1	0.30	122.	0.4	5.7
10	<0.4	2790	80.3	<1	0.74	42.6	0.4	41.
11	<0.4	6380	90.2	<1	0.40	64.3	0.4	6.7
12	0.5	4450	55.8	<1	1.5	63.3	2.6	38.
13	<0.4	11300	13.0	<1	0.40	77.9	0.6	22.
14	<0.4	16100	50.8	<1	0.98	68.8	7.1	17.
15	<0.4	4200	83.4	<1	0.64	52.7	0.95	16.
Mean	-	6756	128.9	-	0.66	74.6	1.43	18.
SD	-	3406	114.6	-	0.45	41.2	1.89	11.

Figure 1. Location of RUby Lake National wildlife Refuge in Nevada, and location of sampling sites (numbered 1 to 15) for collection of water, sediment, and aquatic vegetation on September 15, 1993.


Wells
Exit 321
Elko
RUBY LAKE
N.W.R.
NEVADA
UTAH
Eureka
Ely
AREA
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NORTH
SUMP
Collection Ditch
UNIT 10
CCC DIKE
UNIT 13
EAST
SUMP
BOUNDARY
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UNIT
20
STATE FISH HATCHERY
UNIT
SHANTY TOWN
BROWN DIKE
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